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# OLFACTORY DISTURBANCES IN MAN FOLLOWING EXPOSURE TO RADIATION

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## ABSTRACT

Disruptions in olfaction have been studied based on the observation of the general reaction of the human organism subjected to X-ray radiation in connection with mammary gland tumors. Changes in the olfactory analyzer were recorded by means of the Frolov-Amirov olfactometer. Additional experiments were conducted with patients who were given caffeine to accentuate the sensitivity of their olfactory analyzer. The results of the investigations correlated with the complaints of patients subjected to radiation who experienced olfactory disturbances have convinced the author that such disturbances involve changes in the central nervous system and do not represent true hyperosmia since the subjective accentuation of olfaction during radiation treatment is not accompanied by a decrease in the thresholds of olfaction.

The question of disruptions in olfaction during radiation sickness has been studied little although this disturbance is frequently observed. Indications of olfactory disturbances in man under conditions of radiation which have been reported in the literature pertain both to professional radiation sickness (refs. 5, 6) as well as to radiation sickness which occurs as a result of the therapeutic application of ionizing radiation (refs. 4, 9). However, we have not found reports on objectively recorded changes in the olfactory analyzer during radiation therapy. /26*

Olfactory disruptions during radiation pathology have been noted in experiments. The observations made by I. A. Pigalev (ref. 7) on dogs which have been poisoned with radioactive substances have made it possible for the author to state that these animals have a lowered orientation reflex to the smell of food.

*Numbers given in margin indicate pagination in original foreign text.

Disruptions in the olfactory analyzer which take place under the influence of radiation are also confirmed by morphological investigations. Hicks and Montgomery refer to individual necrosis of cells in the granular layer of the olfactory bulbs for mice and rats which have been subjected to radiation in doses greater than 1200 R.

Olfactory disturbances during radiation sickness caused by the thera- /27
peutic application of penetrating radiation are manifested by the accentuation of olfactory sensations and the occurrence of olfactory hallucinations. For example, from the complaints of patients we learn that smells which were pleasant in the past produce nausea. Also, smells which were not noticed before become unpleasant ("the typographic ink of a newly received magazine has a bad smell," "in the garden the trees smell of bed bugs"). A patient who has smoked for many years without finding the smell of tobacco to be objectionable now finds it irritating. Either all odors or specific ones become objectionable. Disruptions in the identification of odor sensations are also encountered. Mint odor, for example, is perceived as the odor of rotten eggs or the odor of pitch.

In describing olfactory hallucinations we wish to point out that hallucination odors described by patients subjected to radiation are usually unpleasant: they imagine the "smell of corpses," the "smell of burning rubber, burning hair or electrical devices," the "smell of metal" and the "smell of gun powder." In specific cases the patients even indicate the location of the hallucination smell. Thus the "smell of metal" according to a patient is felt in the throat.

In a series of cases irradiated patients are pursued by unique odors which they are unable to describe.

Hallucinatory smells trouble the patients at home, on the street and particularly on the premises of the clinic where they were subjected to radiation and even when they approach the clinic building.

Many patients enter this building covering their nose with a handkerchief because if they inhale the air of the building they get an acute attack of nausea and feel like vomiting.

The present investigation is based on the observations of the general reaction of the human organism subjected to radiation either for the purpose of prophylaxis after the removal of mammary glands due to tumors (21 people) or during the period before surgery due to limited tumors in the mammary glands (5 people). The patients were of different ages which varied from 31 to 63. The patients were subjected to X-ray radiation.

Irradiation was carried out under the following conditions: RUM-3 equipment, voltage of 180 kV, current of 15 mA, filter consisting of 0.5 mm Cu and 1 mm Al, skin-focus distance of 30 cm, field of radiation with dimensions of

6 X 8 and 10 X 15 cm. The radiation dose power was varied from 46 R/min to 62 R/min.

The left or right side of the thorax front was subjected to radiation. Six radiation fields were used: two fields in the region of the post-operation scar (in the case of irradiation before the operation--the inner or outer quadrants of the mammary glands) the zones above and below the clavicle, the region of the sternum, and the region of the axilla.

The single radiation dose for each field was 250 R, while the total dose was 1250 R. The overall dose for all of the fields was 7200 R. Each day two of the six fields were subjected to radiation so that the daily radiation dose was 500 or 400 R. When single dosages of 200 R were used, total dose was 7200 R.

The recording of changes in the olfactory analyzer was accomplished by means of the 0-4 olfactometer designed by Frolov-Amirov. The device is based on supplying odorous substance into a continuous air stream. The stream of air comes from a blower and is fed to the test subject by connecting tubes through the device. The odorous substance enters the stream by air suction from the vessel containing mint oil. In the process it passes through a rubber section of the tube which is compressed with a precision micrometer. The slit in the tube can be varied at will by means of the micrometer and can be made larger or smaller with an accuracy up to 0.01 mm, thereby providing for the metering of the odorous substance.

During olfactometric investigations we produced a definite threshold /28 of olfaction, the recording of the latent period and time of following reaction and the determination of time for the onset of adaptation to the odor.

Olfactometric investigations were performed during a period of 2-4 days before the beginning of irradiation and then before each conducted irradiation throughout the entire course of X-ray therapy.

In a series of cases olfactometric observations were continued after completion of the radiation course until the threshold indicators of olfaction were normalized.

Before proceeding with the study of changes occuring in the olfactory analyzer under the influence of radiation we performed single control investigations of 76 people.

These data permitted us to establish the possible variations in the olfactory analyzer sensitivity in the norm. A substantial spread in the olfaction threshold was established for the various test subjects. This spread was within the limits of the 22 division of the micrometer scale which, according to our measurements, corresponded to a concentration from $5 \times 10^{-8}$ to $200 \times 10^{-8}$ grams per liter of air.

Having thus become acquainted with the possible variations in the degree of olfactory analyzer sensitivity in the norm we proceeded with the study of possible physiological variations in the olfaction threshold, under dynamic conditions, of five people who were not given radiation treatment. Tests were conducted daily for a period of 21-29 days and periodically with different time intervals (from 15 days to 4-10 months). The physiological oscillations in the olfaction threshold took place within insignificant limits (1-2 divisions of the micrometer scale).

We performed 720 olfactometric examinations to evaluate the degree of olfactory analyzer sensitivity both in the norm and under conditions of reaction to radiation.

The patients were divided into groups according to the degree of olfactory analyzer sensitivity in the initial state (before exposure to radiation).

The first group contained 8 persons with a low initial olfaction threshold, i.e., with a high olfactory analyzer sensitivity. The initial olfaction threshold of test subjects in this group measures 4.77 to 4.85 on the relative scale of the micrometer which in absolute units of concentration is $6 \times 10^{-8}$ to $26 \times 10^{-8}$ grams per liter of air. The second group contained 12 persons with a high initial olfaction threshold measuring from 4.86 to 4.92 on the relative micrometer scale, which corresponds from $40 \times 10^{-8}$ to $100 \times 10^{-8}$ grams per liter of air in absolute units (the average sensitivity of the olfactory analyzer). The third group contained six persons with a high initial olfaction threshold, i.e., with a low initial olfactory analyzer sensitivity. In terms of the relative units the olfaction threshold varied from 4.93 to 4.96 divisions of the micrometer scale which corresponds from $118 \times 10^{-8}$ to $200 \times 10^{-8}$ grams per liter of air in absolute units.

A clear relationship was established between the variation in the sensitivity of the olfactory analyzer and its functional state before the beginning of irradiation. Thus, when the initial sensitivity of the olfactory analyzer was high, the effect of radiation was to produce a substantial rise in the olfaction thresholds. When the initial sensitivity of the olfactory analyzer was of the average value there was a pronounced instability in the values of the threshold indicators during the radiation process.

Finally, when the initial analyzer sensitivity was low, the action of radiation produced almost no change in its level (fig. 1). /29

In most of the observations the time required for the olfactory organ to adapt itself to the smell of mint decreased under the influence of radiation. The latent period and time of the following reaction varied in a different manner. All the observed patients except one exhibited a general reaction of the organism to the radiation treatment, but the extent of its manifestation varied.

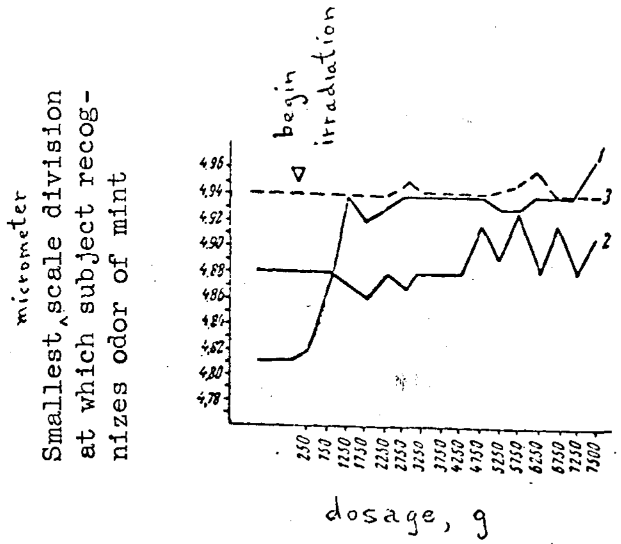


Figure 1. The nature of variation in the activity of the olfactory analyzer during irradiation as a function of the value of olfaction threshold before the beginning of radiation. The figure shows the olfactogram characteristics for three patients taken from each of the three different groups. 1, patient P. (first group); 2, patient K (second group); 3, patient C (third group).

The nature of the disruptions in the activity of the olfactory analyzer during radiation which we established was clarified by certain additional investigations.

In investigations with the application of caffeine loading (five persons were examined 30 minutes after they were given caffeine in the form of a 0.2 gram dose of benzoin-sodium salt), an increase in the sensitivity of the analyzer is observed (a lowering of the threshold and an increase in the time required for adaptation to occur). After the application of large total doses of radiation this effect becomes less pronounced (fig. 2). This situation may be explained by the fact that radiation decreases the functional activity of the central nervous system (it lowers the efficiency limit of cortical centers).

Parallel examinations of three patients by the olfactometric and electroencephalographic methods carried out by us in collaboration with N.G. Darenskaya permits us to speak with greater confidence concerning the central nature of disruptions associated with the activity of the olfactory analyzer under the influence of radiation. Variations in the olfactogram and in the EEG have the same nature, pointing to the lowering of the functional activity of the central nervous system (CNS). A decrease in the sensitivity of the olfactory analyzer takes place on the background of a deepening depression of the brain biocurrents.

The central nature of disruptions in the activity of the olfactory analyzer during irradiation is also confirmed by the complaints of patients regarding the

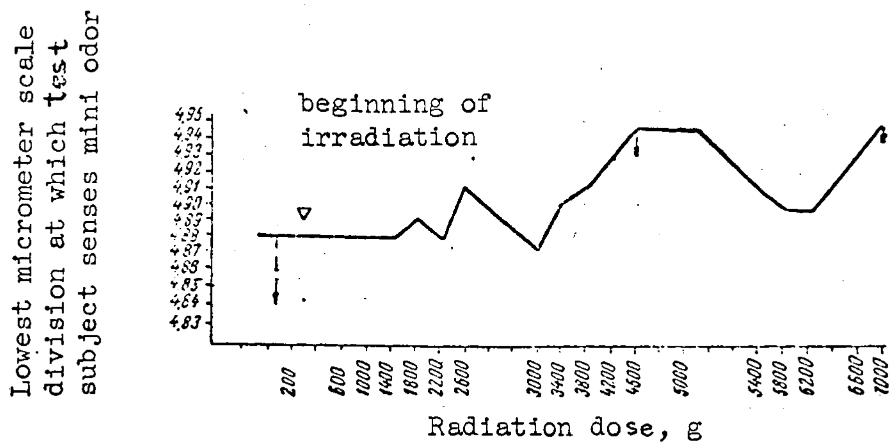


Figure 2. The lowering of olfaction threshold to the smell of mint oil after taking caffeine (shown with a broken arrow) in patient B. Examination 30 minutes after administering caffeine and a dose of 0.2 R.

disruption of their olfaction. Thus the occurrence of olfactory hallucinations can be explained by the development of phase states of the brain cortex peculiar to radiation sickness and produced by the action of ionizing radiations on the organism.

The distortion of the olfactory sensations in patients subjected to radiation may be referred to variants of qualitative disruptions of the olfactory analyzer activity which are defined by the term "paraosmia."

The accentuation of olfaction should not be looked upon as a true /30
hyperosmia described by L.G. Chlenov but as an olfactory hyperpathia. The fact that the accentuation of olfaction in our patients is not a true hyperosmia is indicated by the absence of the lowering of olfaction thresholds during complaints concerning the accentuation of olfactory sensations.

Thus during radiation sickness there are complaints concerning olfactory disruptions which indicate that there is damage to the cortex olfactory centers and paths.

## Conclusions

1. People subjected to the action of radiation undergo a disruption of the olfactory analyzer activity. These disruption are manifested by patients' complaints concerning the accentuation and distortion of olfaction and the occurrence of olfactory hallucinations. In the course of a special examination, a change in the olfaction threshold and the shortening of time required to produce adaptation are detected.

2. The investigations conducted establish a central mechanism for the disruption of the olfactory analyzer activity in people under conditions of irradiation. The nature of changes in the sensitivity of the olfactory analyzer is affected by its functional state before radiation is applied.

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